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HEAVY METAL CONTAMINATION OF THE SALMON RIVER, NOVA SCOTIA, IN THE VICINITY OF YAVA MINES LEAD MINE

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Atlantic Region

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HEAVY METAL CONTAMINATION OF THE SALMON RIVER, NOVA SCOTIA, IN THE VICINITY OF YAVA MINES LEAD MINE

by

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Environment Canada
Atlantic Region

January, 1983

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ABSTRACT

Yava Mines Limited operated a 600 ton per day lead mine on the Salmon River on Cape Breton Island, Nova Scotia, from 1979 to late 1981. In July of 1981, in order to evaluate the impact of this activity on the receiving water, water, sediment and biota were sampled in the vicinity of the mining operation.

While the effects on the water column are localized within the first few metres of the mouth of the discharge brook, the sediment is contaminated with heavy metals within the Salmon River itself. Most of this contamination, which reached values as high as 18,078 µg/g lead, 32.0 µg/g cadmium, 22.8 µg/g copper, and 1,011 µg/g zinc, appeared to be confined to a small cove receiving the discharge. However, sampling was not extensive enough to exclude the possibility of a more widespread dispersal. Some of this contamination may have arisen from land wash through mineralized soils in the area. The relative importance of these two sources could not be established.

Biological analyses indicated a stressed environment exists in the cove. Possible corrections include removal of sediments and/or stream diversion around the contamination.

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1. INTRODUCTION

Yava Mines Limited, a subsidiary of Barymin Explorations Limited, operated a 600 ton per day lead mine on the Salmon River since 1980, which was expanded to 810 tons per day in 1981 (see Figure 1). In October, 1981, the mine went into receivership under the control of Coopers and Lybrand Limited of Toronto, who continued to mine the property. The mine, later in 1981, went into bankruptcy and ceased operation.

The mined ore, which increased from approximately 4 to 4.7% lead was trucked from the mine to a concentrator about 13 km away on Lake Enon, where it was upgraded to approximately 70% then trucked to Sydney, Nova Scotia, for temporary storage until shipped out under long term contract to Metallgesellschaft, A.G. of West Germany. The total reserves have been estimated at 960,000 tons at an average grade of 5.46% lead, which places the life of the mine at approximately 5 to 10 years, but further exploration could extend this time.

The method of extraction was by room and pillar techniques using trackless mining equipment. Mine drainage, in the order of 2,600 to 5,200 m^3/day at a concentration of approximately 50 to 60 mg/l lead, was allowed to settle in a series of ponds before being discharged to the Salmon River. Since this discharge increased in concentration of lead to a level that caused some concern, an investigation of the possible effects of the discharge on the receiving water was begun during the summer of 1981 by Environment Canada. At the same time, discussions were begun with the company and NSDOE to find a solution. The mine responded by constructing an additional settling pond, which began operation in August, 1981.

The following report describes the results of the Salmon River survey done in July, 1981, before the new pond was built.

The layout of the mine is shown in Figure 2. The mine drained from a single sump to a series of settling ponds. Figure 3 shows

FIGURE 1 - LOCATION OF YAVA MINE AND MILL SITES

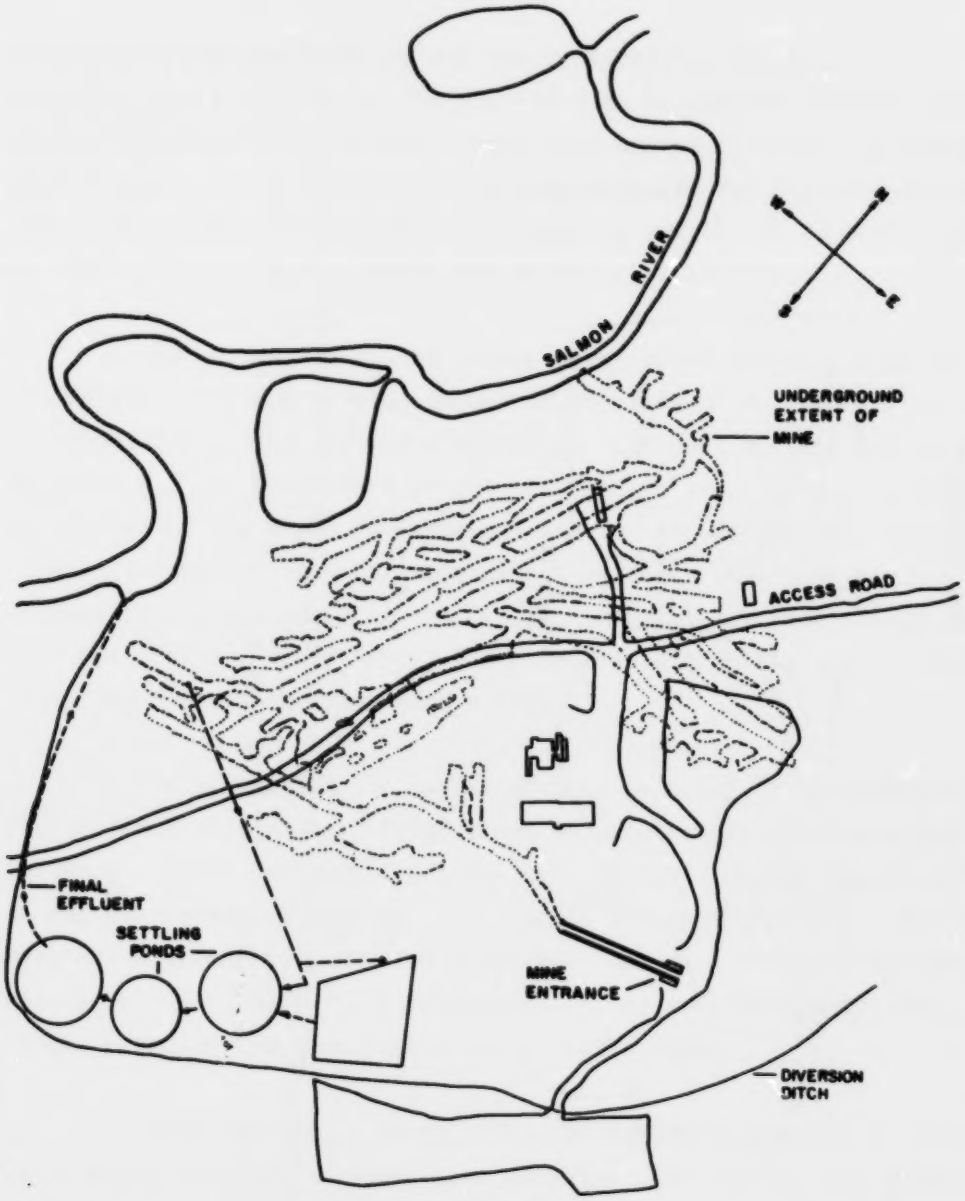


FIGURE 2 - LAYOUT OF YAVA MINE SITE

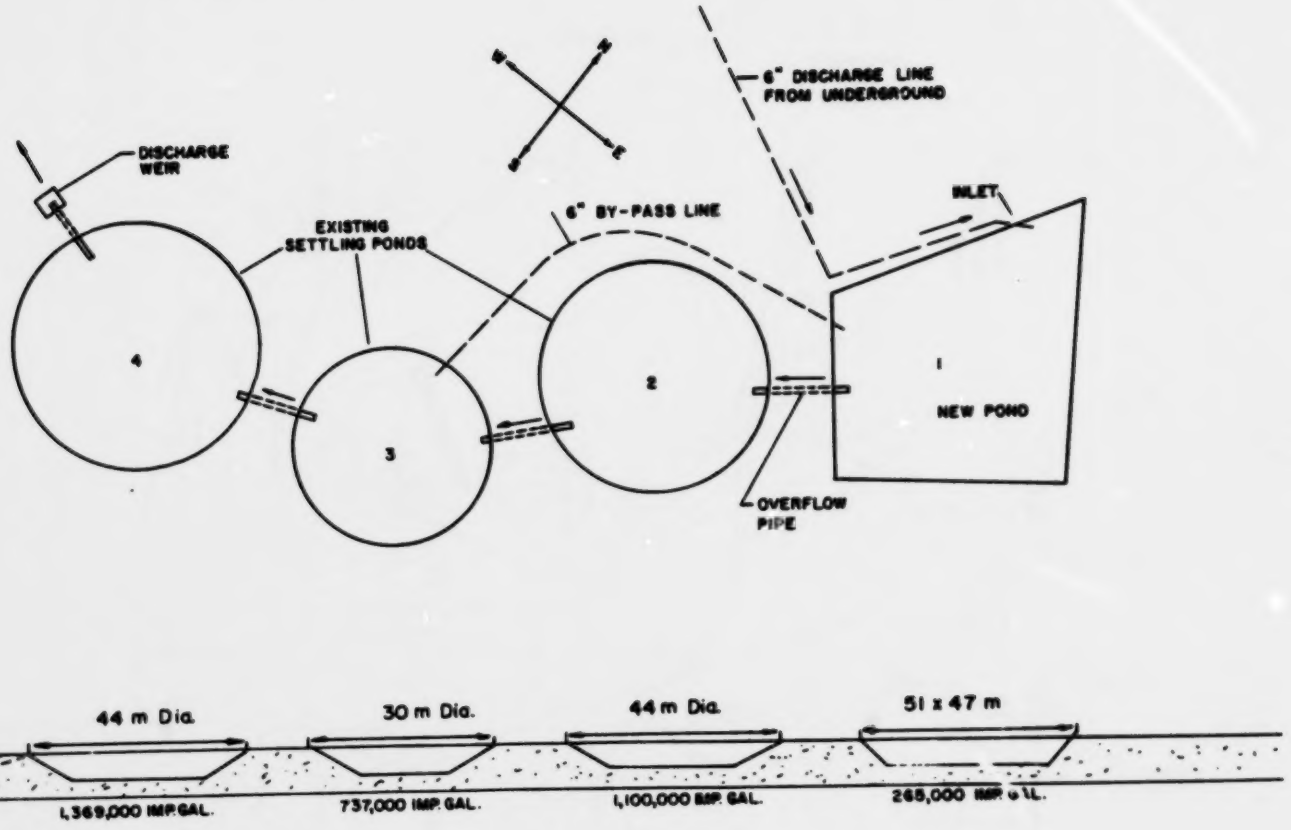


FIGURE 3 - YAVA MINES TREATMENT FACILITY

diagramatically the capacity and basic structures of these ponds. The original design called for the overflows to be through decants made from culverts covered with burlap. These have proved difficult to operate and were removed. Simple settling had been adequate for treating the mine water, since the mine is not acid producing and the pH is nearly neutral. At these pH's the heavy metals are primarily insoluble.

Water quality of the Salmon River above the discharge is listed in Table 1. This data, even though it consists of one sample, is probably representative of background conditions. Effluent quality may be found in Appendix A. The parameters of primary concern are lead and suspended solids, which are shown in Figures 4 and 5. As one can see, the concentrations for both of these have frequently been greater than those allowed in a grab sample by the Canada Fisheries Act regulations covering base metal mining operations. These permissible levels are 0.4 mg/l for lead, and 50 mg/l for suspended solids.

In evaluating the causes of this problem, it is important to look at the flows (Figure 6). These flows have increased since the opening of the mine. While the settling times were adequate during the first few months of operation, they did not satisfy the maximum flows. In 1979, Montreal Engineering predicted a maximum flow of 1,000 Imperial gallons per minute (6,545 m^3/day). The inadequacy of the treatment ponds has, since, prompted the construction of a fourth pond.

Near the end of March, 1981, an incident occurred at the mine which might have had a significant effect on the river. The failure of a generator and a backup generator at the same time brought about the near loss of the mine. In order to make more headway on the water level, the mine bypassed the treatment ponds and discharged directly to the river. The discharge, which began March 28, was located at the point where the pipe comes out of the mine from the sump and flowed over land to the river. The problem was corrected by the morning of March 31.

TABLE 1 - WATER QUALITY OF THE SALMON RIVER 1 KM UPSTREAM FROM THE FINAL EFFLUENT - COLLECTED AUGUST 7, 1981, BY NOVA SCOTIA DEPARTMENT OF ENVIRONMENT AND ANALYZED BY DEPARTMENT OF PATHOLOGY, VICTORIA GENERAL HOSPITAL

sodium	- 5.0 mg/l
potassium	- 0.4 mg/l
calcium	- 8.2 mg/l
magnesium	- 1.5 mg/l
hardness	- 27 mg/l
alkalinity	- 19 mg/l
sulfate	- 7.2 mg/l
chloride	- 6.7 mg/l
fluoride	- <0.1 mg/l
silica, reactive	- 4.0 mg/l
phosphate, ortho	- <0.02 mg/l
nitrate + nitrite (as N)	- <0.05 mg/l
ammonia (as N)	- <0.05 mg/l
arsenic	- <0.005
iron	- 0.27
manganese	- 0.05
lead	- 0.005
copper	- <0.01
zinc	- <0.01
total dissolved solids	- 59 mg/l
suspended solids	- 2.8 mg/l
colour	- 50 T.C.U.
turbidity	- 2.7 J.T.U.
conductivity	- 58 µmho/cm
pH	- 6.9

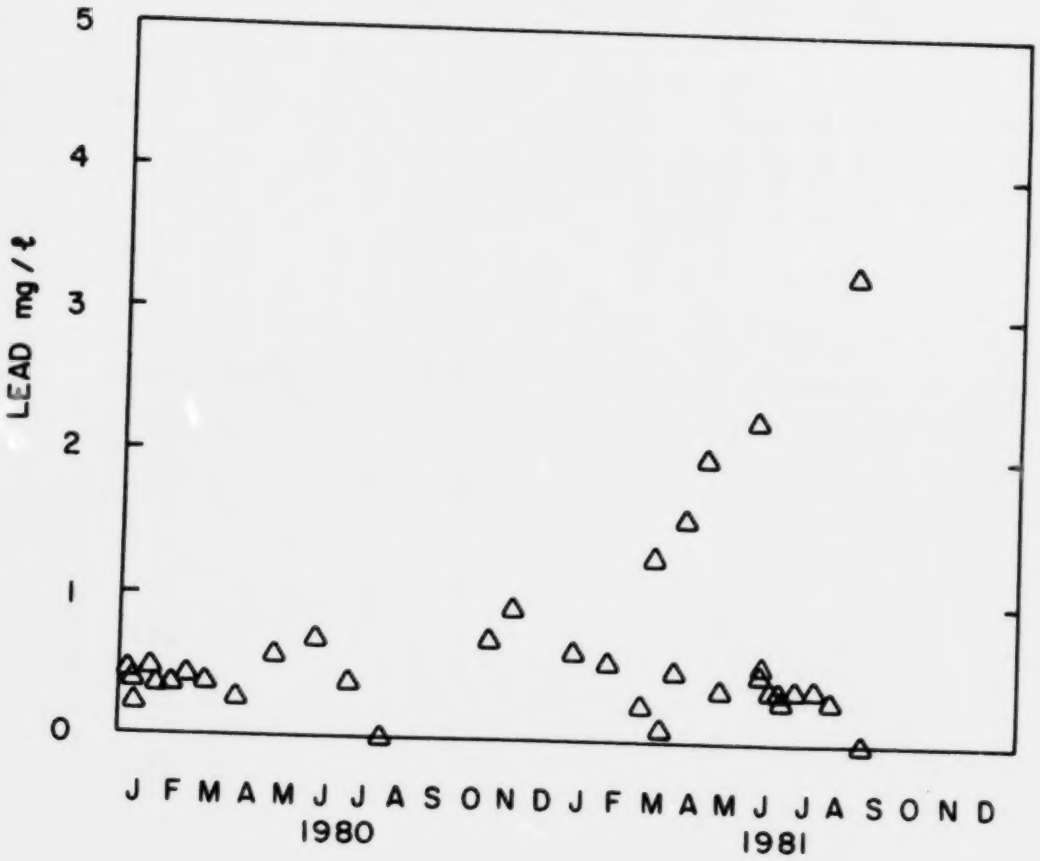


FIGURE 4 - YAVA MINES FINAL EFFLUENT TOTAL LEAD CONCENTRATIONS

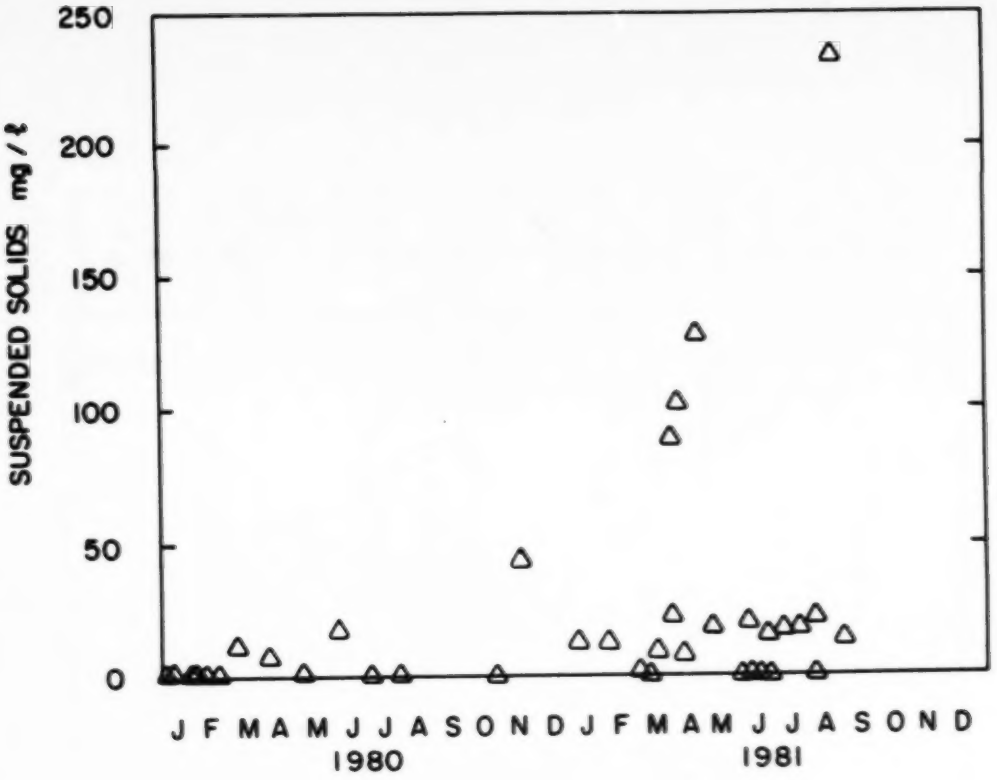


FIGURE 5 - YAVA MINES FINAL EFFLUENT SUSPENDED SOLIDS CONCENTRATIONS

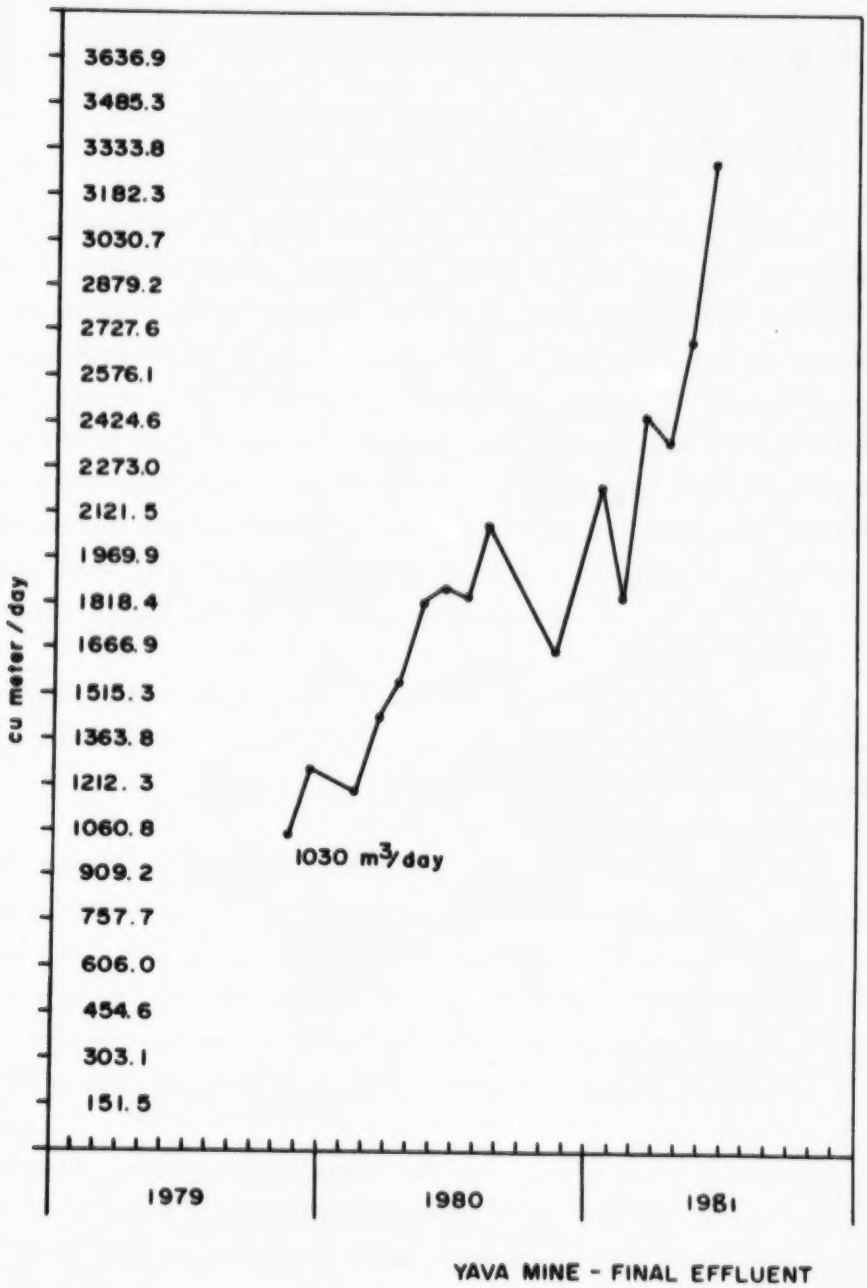


FIGURE 6 - YAVA MINES FINAL EFFLUENT FLOWS

2. METHODS

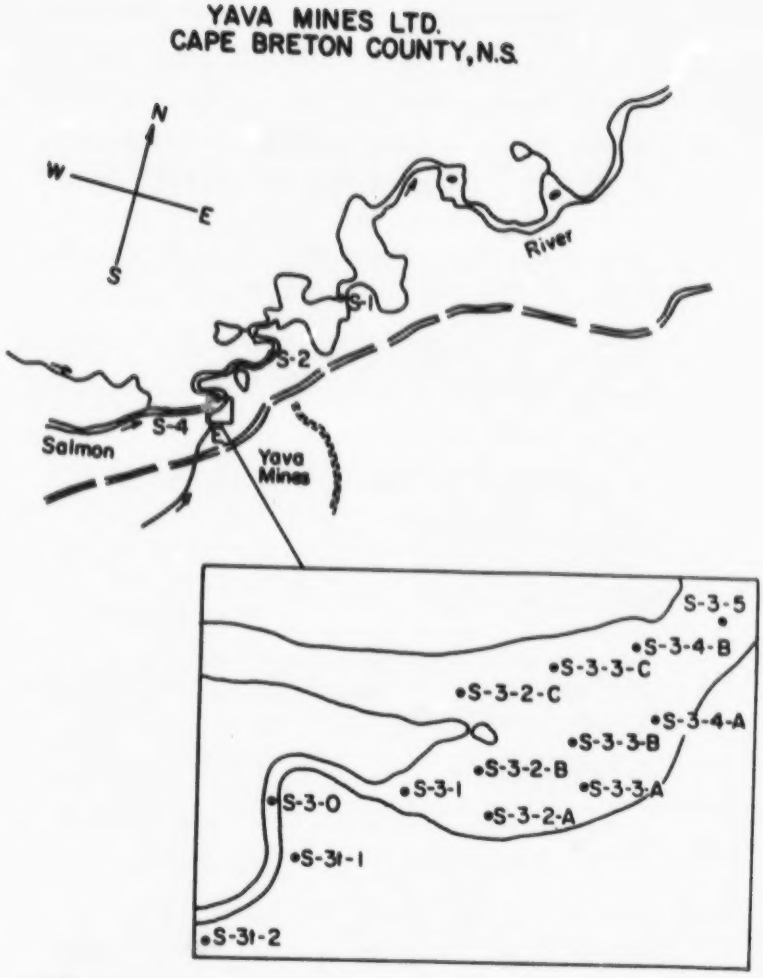
2.1 Salmon River Sampling

Before the development of the mine site, an environmental baseline study was prepared by Dames and Moore Limited (1979). This report indicated that before mine operation, there were low concentrations of heavy metals in the water column, but that there were isolated areas in the river where sediment concentrations of lead reached as high as 822 µg/g. Apart from these areas, the stream sediments were found to be in the more common range of less than 60 µg/g. Unfortunately, the cove where the contamination was found in this study was not measured in the earlier investigation. In a report prepared by R.A. Geisler, soil analyses in the area of the mine before it was developed (1962) showed high in lead.

Water flows and discharge quality were estimated by Montreal Engineering (1979). Details of the mine development itself was prepared by Yava Mines Limited (1977).

Sampling of the Salmon River took place on July 21 and 22, 1981. The area did not receive heavy rains at least two or three days previous. Fog and mist with several light showers occurred on July 21. A heavy rain had fallen in the evening of July 21 and the water level in the river had risen 20 to 25 cm over night and was still rising during sampling, even though no precipitation was experienced during the second day of sampling.

Figure 7 and Table 2 show the sampling locations. At stations S-1, S-2 and S-3-2, benthic invertebrate samples were obtained by using a Peterson dredge. About three dredges were collected at each location and combined for identification and enumeration. At station S-3-2-C, a long handled five mesh net was used at four locations in the stream and combined. At station S-4, a Surber sampler was used at four locations equidistant from each other on a transect line across the river. In shallow areas, sediment samples were obtained with a plastic scoop.



NOTE:

1.) Sampling stations from 1981 recieving water survey are located as indicated
2.) Inset shows sub-stations of sampling site S-3
3.) Arrows show direction of river flow
E - area where Yava Mines effluent joins Salmon River system

FIGURE 7 - SAMPLING LOCATIONS IN THE SALMON RIVER

TABLE 2 - SAMPLING STATION DESCRIPTIONS, SALMON RIVER, CAPE BRETON COUNTY

Station No.	Location and Description	Watenis No.
S-4	Salmon River - 200 m upstream of confluence of Salmon River with effluent discharge from Yava Mines. Rock and gravel stream bed; flow approx. 0.6 m^3/S; surface velocity approx. 0.2 m^2/m. Average depth was determined as an average of three depths taken on a perpendicular line across the river. One depth at midstream and one at each quarter.	SALMRV01
S-3T-1	Terrestrial; 100 metres upstream along effluent discharge stream; 5 metres from the stream towards the east. No description.	SALMRV02
S-3T-2	Terrestrial; 150 metres upstream along effluent discharge stream; 5 metres from the stream towards the east. No description.	SALMRV02
S-3-0	Effluent discharge stream; 75 metres upstream of its confluence with Salmon River. Mud stream bed; depth approx. 0.75 m; no vascular plant growth. Since station S-3 was set up as a grid system, flow and surface values were not quantitatively determined at each substation. Qualitatively, it can be said that stations S-3-2-C, S-3-3-C, S-3-4-B, S-3-5 were positioned in the main current of the river, with the surface velocity approximately equal to that of station S-4. The remainder of the S-3 substations were not at all influenced by the main river current but only by the effluent discharge stream. The surface velocity at these stations was almost negligible. Vascular plants most common in the Salmon River system were: Equisetum, water lilies, and various aquatic grases	SALMRV02

TABLE 2 (Continued)

Station No.	Location and Description	Watenis No.
S-3-1	Salmon River; in cove directly at mouth of Yava effluent discharge. Mud stream bed; depth approx. 0.75 m; vascular plant growth.	SALMRV02
S-3-2-A	Salmon River; in cove 20 metres downstream of confluence with effluent discharge 7 metres from right bank. Mud stream bed; depth approx. 0.75 m; vascular plant growth.	SALMRV02
S-3-2-B	Salmon River; in cove 20 metres downstream of confluence with effluent discharge 15 metres from right bank. Mud stream bed, depth approx. 0.50 m; vascular plant growth.	SALMRV02
S-3-2-C	Salmon River; in main stream 20 metres downstream of confluence with effluent discharge 8 metres from left bank. Rock and gravel stream bed; depth approx. 1.0 m; no vascular plant growth.	SALMRV02
S-3-3-A	Salmon River; in cove 40 metres downstream of confluence with effluent discharge 10 metres from right bank. Mud stream bed; depth approx. 0.75 m; vascular plant growth.	SALMRV02
S-3-3-B	Salmon River; in cove 40 metres downstream of confluence with effluent discharge 20 metres from right bank. Mud stream bed; depth approx. 0.5 m; vascular plant growth.	SALMRV02

TABLE 2 (Continued)

Station No.	Location and Description	Watenis No.
S-3-3-C	Salmon River; in main stream 40 metres downstream of confluence with effluent discharge 8 metres from left bank. Rock and gravel stream bed; depth approx. 1.25; no vascular plant growth	SALMRV02
S-3-4-A	Salmon River; in cove 75 metres downstream of confluence with effluent discharge 10 metres from right bank. Mud stream bed; depth approx. 10 m; vascular plant growth.	SALMRV02
S-3-4-B	Salmon River; in main stream 75 metres downstream of confluence with effluent discharge 8 metres from left bank. Rock and gravel stream bed; depth approx. 1.75 m; no vascular plant growth.	SALMRV02
S-3-5	Salmon River; midstream at bend in river just below cove 100 metres downstream of confluence with effluent discharge. Clay stream bed; depth approx. 2.50 m; no vascular plant growth.	SALMRV02
S-2	Salmon River; 20 metres upstream of bridge at the Yava Mines pumphouse intake. Rock bed in midstream; mud, sand, gravel and detrilus near both banks; flow approx. 1.80 m^3; surface velocity approx. 0.1 m/S; average depth 1.85; vascular plant growth near both banks only.	SALMRV03

TABLE 2 (Continued)

Station No.	Location and Description	Watenis No.
S-1	Salmon River; midstream of river where it leaves the first large pond downstream of the Yava Mines property. Rock bed in midstream; mud, sand, gravel and detrilus near both banks; flow approx. 1.80 m^3/S; surface velocity approx. 0.05 m/S; average depth 1.55 m; vascular plant growth near both banks only.	SALMRV04

2.2 Sample Analyses

Water samples and sediment samples were collected for chemical analysis. Water samples were analyzed for the following parameters: hardness, lead, copper, zinc, cadmium and iron (in the laboratory). Also, a field analysis was carried out to determine temperature and pH. Sediment samples were analyzed for: lead, copper, cadmium, zinc and iron (all sediment values are expressed on a dry weight basis).

All water samples that were collected were taken from the surface of the water body, either at midstream or at specific grid locations.

Water samples were collected in 500 ml or 250 ml polyethylene bottles that had been cleaned prior to use with nitric acid. After collection, the samples were acidified with nitric acid to prevent the precipitation of dissolved metals. Analyses were performed on these samples without filtering. Sediment samples were taken from the top layer of sediment. Certain stations were analyzed for sediment only; also in certain areas, sediment samples were not obtainable because of the nature of the river bed. All sediment samples were collected in pre-sealed sterile plastic bags.

All water and sediment samples collected were analyzed for chemical parameters by the Environmental Protection Service Laboratory in Dartmouth, Nova Scotia; the results are tabulated in Table 3.

Several physical characteristics of the stations sampled were also determined. These included an estimation of flow, surface velocity and depth. To obtain surface velocity, a floating object was tossed into the river above the sampling station and the time elapsed as it travelled a set distance (usually 5 or 10 metres) through the station was recorded. To obtain flow, the value for surface velocity was used as the speed of the water in the river passed a certain transect. The distance from bank to

TABLE 3 - CHEMICAL ANALYSES - SALMON RIVER, CAPE BRETON COUNTY, NOVA SCOTIA

tation	Date 1981	Water Quality Analysis								Sediment Analysis				
		Temp. °C (field)	Ph (field)	Hardness ppm	Cu ppm	Cd ppm	Pb ppm	Zn ppm	Fe ppm	Cu ppm	Cd ppm	Pb ppm	Zn ppm	Fe ppm
-4	21/07	17.0	6.50	20	<0.01	<0.01	<0.02	<0.01	0.46	4.4	0.3	48	118	17640
-3T-1	-	-	-	-	-	-	-	-	-	17.2	1.6	12132	762	25338
-3T-2	-	-	-	-	-	-	-	-	-	20	4.0	4918	731	24984
-3-0	22/07	-	-	110	<0.01	<0.01	0.14	<0.01	0.28	13.9	2.8	5866	496	16559
-3-1	22/07	16.0	7.70	110	<0.01	<0.01	0.13	<0.01	0.26	16.8	1.2	10444	517	18097
-3-2-A	22/07	16.0	7.00	30	<0.01	<0.01	<0.02	<0.01	0.58	22.8	3.8	4178	558	18169
-3-2-B	22/07	16.0	7.10	40	<0.01	<0.01	0.05	<0.01	0.64	17.4	1.8	10152	557	20866
-3-2-C	22/07	16.0	6.80	17	<0.01	<0.01	<0.02	<0.01	0.86	-	-	-	-	-
-3-3-A	22/07	14.0	6.90	25	<0.01	<0.01	<0.02	<0.01	0.60	16.6	32.0	1998	1011	15100
-3-3-B	22/07	16.0	6.90	25	<0.01	<0.01	<0.02	<0.01	0.58	14.6	2.3	18078	472	21048
-3-3-C	22/07	-	-	16	<0.01	<0.01	<0.02	<0.01	0.78	-	-	-	-	-
-3-4-A	22/07	16.0	6.90	23	<0.01	<0.01	<0.02	<0.01	0.69	14.6	2.2	2591	384	14750
-3-4-B	-	-	-	17	<0.01	<0.01	<0.02	<0.01	0.72	-	-	-	-	-
-3-5	22/07	-	-	16	<0.01	<0.01	<0.02	<0.01	0.76	16.6	0.9	258	333	18459
-2	21/07	19.0	6.30	35	<0.01	<0.01	<0.02	<0.01	0.48	1.7	0.2	48	63	15603
-1	21/07	19.5	5.80	30	<0.01	<0.01	<0.02	<0.01	0.41	5.8	1.2	215	161	14376

te: Stations S-3T-1; S-3T-2 - terrestrial, therefore no water sample.
Stations S-3-2-C; S-3-3C; S-3-4-B - water sample only.

bank along this transect was measured, and three depths along it recorded (midstream, and at each quarter). These measurements were used to obtain a cross-sectional area of the river. The rate of the river flowing through or past the known transect area determined a rough estimate of the flow of the river.

The average depth of the river was determined by averaging the three depths measured along the transect, this actually gave the average depth of the middle half of the river (not the entire river) or the "channel". At the stations where a grid network was set up, depth was recorded as a single measurement at each substation.

The benthic samples were collected in polyethylene bottles or sturdy plastic bags until a time and place was available to sort through the samples and pick out living animals. Invertebrates found in the samples were preserved in glass vials with Kahle's fluid[1]. Identification of the invertebrates was carried out with the aid of the following references: Claassen, 1931; Edmondson, 1959; Herring and Ashlock, 1971; Johannsen, 1969; Needham et al., 1972; Pennak, 1955; Peterson, 1951; Usinger, 1956; Walker, 1953; Wiggins, 1977. Most animals were identified to Genus, but several could be determined no further than Family or Order.

Also collected from the rivers surveyed were samples of benthic diatoms (microscopic Chrysophyta). To obtain benthic diatoms, rocks were removed from the river bed of each station and encrustings on the rocks scraped off with a scalpel. The scrapings were collected in polyethylene

---

[1] A preservative, particularly effective for aquatic insects, prepared by combining: 15 parts per volume ethanol, 6 parts per volume foreralin (37% formaldehyde), 1 part per volume glacial acetic acid and 30 parts per volume distilled water.

bottles with water and preserved with acid lugols preservative[2]. (Note: Station Knights BK-2 and Salmon River 3-5 diatom samples were taken from the surface of the sediments instead of rocks.)

To prepare the diatoms for observation, it was decided that a technique would be used that would remove all organic material (both the living cell material from the diatoms and also any organic debris collected from the scrapings). This technique involved the use of concentrated sulfuric acid, and when complete only the silica frustrules of the diatoms and inorganic sediments remained.

The samples had been preserved in 500 ml polyethylene bottles. Excess water and preservative were decanted away; the sample was then transferred to a centrifuge tube and was centrifuged at 1,000 G for 10 minutes to separate the sample from any remaining liquid. The sample (with as much liquid as possible removed) was placed in a small beaker with concentrated sulfuric acid (about a 2:1 volume to volume ratio; sulfuric acid: sample). The acid and sample was heated on low heat and stirred (constantly with a magnetic stirrer) to aid in the digestion of the organics.

Digestion of the organic material was complete after about 20-30 minutes (depending on the size of the sample). There was no definite indications that digestion was completed, other than the sample turning very black and no organic material seen suspended in the liquid.

---

[2] A preservative used for algae, added in a 1:10 preservative to sample ratio. Prepared with 10 g iodine; 20 g potassium iodide; 20 g glacial acetic acid; 200 ml distilled water.

After the surfuric acid had digested the organic material, potassium dichromate crystals were slowly added until the liquid changed to a brownish colour. When the crystals had dissolved, the liquid was removed from the hotplate and allowed to cool.

When the beaker was cool enough to touch, the sample and acid was transferred to a centrifuge tube and centrifuged at 1,000 G for 10 minutes to separate the acid from the solids (diatom frustrules and sand and sediment grains).

The liquid was decanted from the sample and discarded. The sample was then washed with distilled water by adding abut 25 mls water to the centrifuge tube, mixing it well with the sample and recentrifuging for 10 minutes at 1,000 G's.

After the distilled water rinse, some of the larger sand and sediment grains were removed. The sample was transferred to a beaker and distilled water added. The sample was swirled to get a good mixing effect, then allowed to stand for about 10 seconds (heavy particles settled out, the diatoms remained suspended). The liquid (with the suspended diatoms) was poured into another beaker. The particles left behind were washed once more to assure that as few diatoms as possible were lost.

This procedure was repeated another time to remove as much of the larger inorganic particulate as possible. The distilled water rinse was then repeated.

After two distilled water rinses, the sample was rinsed twice with 100% ethanol. The sample was taken up in about 15-20 mls ethanol, centrifuged for 10 minutes at 1,000 G's, the liquid discarded, and the procedure repeated.

When the second alcohol rinse was completed, the sample was taken up in about 2-5 mls ethanol and stored in a glass vial.

In order that the diatom samples could be observed and individuals identified, it was necessary to prepare permanent mounts (slides) using the samples. When mounting the diatoms, a relatively new mounting medium was used, Cumar R-9. This medium was used particularly to preserve the frustrule detail of the diatoms.

For most of the stations that were sampled, three permanent slides were prepared for each. One to several drops of the sample was placed on each coverslip (depending on the concentration of the sample) and the ethanol allowed to evaporate (the coverslips were placed on a hotplate with low heat to evaporate the alcohol, and also to make the coverslips easier to mount).

The medium was obtained in a crystal form. To be usable, it was therefore dissolved in enough xylene that the solution formed was saturated.

The slides were placed on the hotplate for several minutes to allow then to become warm. Two or three drops of the mounting medium solution were placed on each slide. The heat from the hotplate drove the xylene off in a gaseous form (after being exposed to the heat for several minutes). An indication that the medium was ready for mounting was a brittleness when allowed to cool. When this point was reached, the coverslips were placed on the slide and pressed into place using a teasing needle (from a dissecting kit) and a pencil eraser. The coverslip trapped many air bubbles within the medium; they were removed by carefully applying pressure to all areas of the coverslip. After all or most of the air bubbles were removed, the slides were removed with a scalpel. The slides were labelled and filed until time was available to examine them, identify

the diatoms present, and make a rough estimate of relative abundance at each station.

3. RESULTS

The results of chemical analyses on both the sediment and water samples may be found in Table 3. Most of the water analyses indicate background levels, except for two stations for lead and for hardness. The discharge brook itself (station S-3-0) and the station at the mouth of this brook (S-3-1) indicate lead levels of 0.14 and 0.13 mg/l respectively, and hardness values of 110 mg/l at both locations. Sediment distributions of heavy metals are better described in Figures 8, 9, 10 and 11. In general, very high values occur in the small cove receiving the effluent. These reach as high as 18,078 ppm (1.8%) for lead; 32 ppm for cadmium, 22 ppm for copper, and 1,011 ppm for zinc.

In comparison with the Dames and Moore results from the baseline study, there is evidence of sediment contamination in the Salmon River, at least in the small cove receiving the discharge. The sampling locations outside this area are not extensive enough to exclude the possibility of further dispersion of the contamination.

The results of the identification and enumeration of benthic invertebrates is listed in Table 4. Five stations were sampled for invertebrates. In general, while no stream sampling station was totally devoid of life, there did appear to be organisms normally only surviving in stressed environments in the cove (station 3-1).

While there are variations from station to station in the remaining locations, it is difficult to make out more than subtle trends that would require much more extensive sampling to delineate. A substantial variety of life appears to be present in the main body of the stream at least.

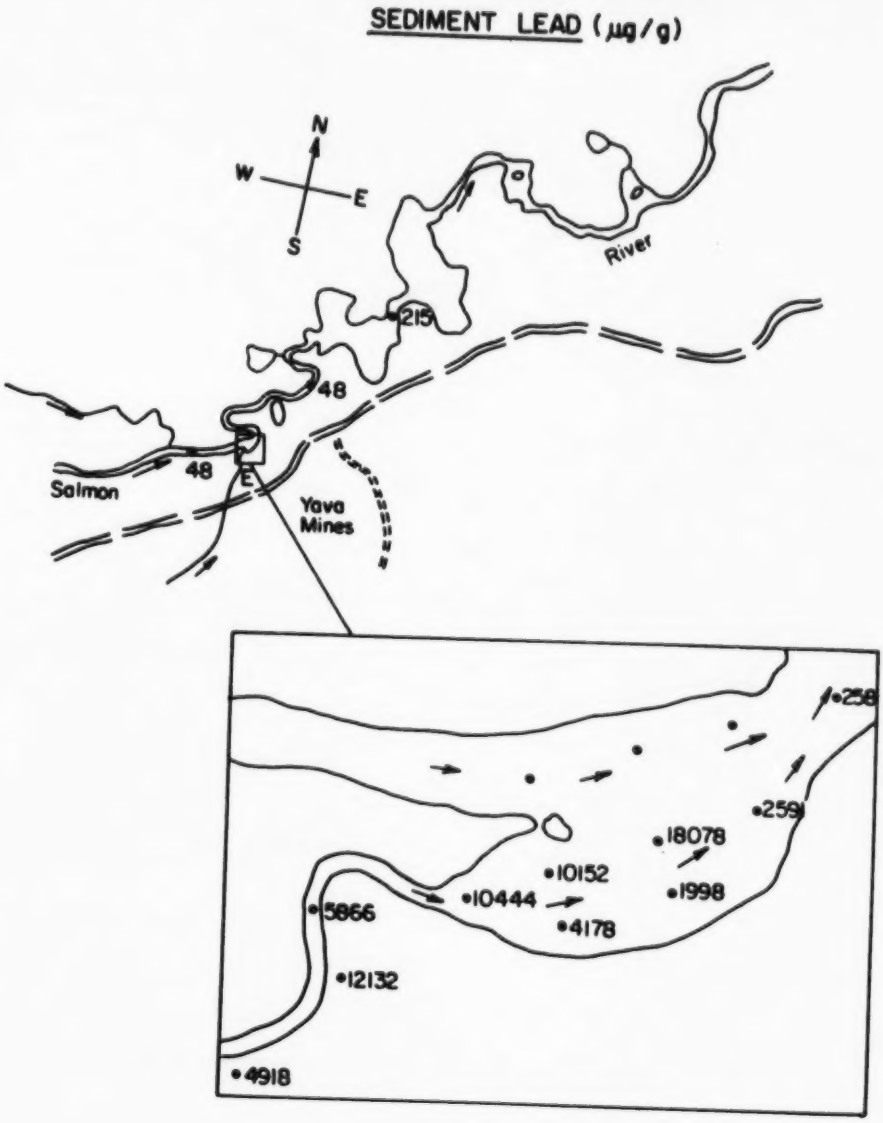


FIGURE 8 - SEDIMENT LEAD CONCENTRATIONS (DRY WEIGHT) IN THE SALMON RIVER IN THE VICINITY OF THE YAVA MINES DISCHARGE

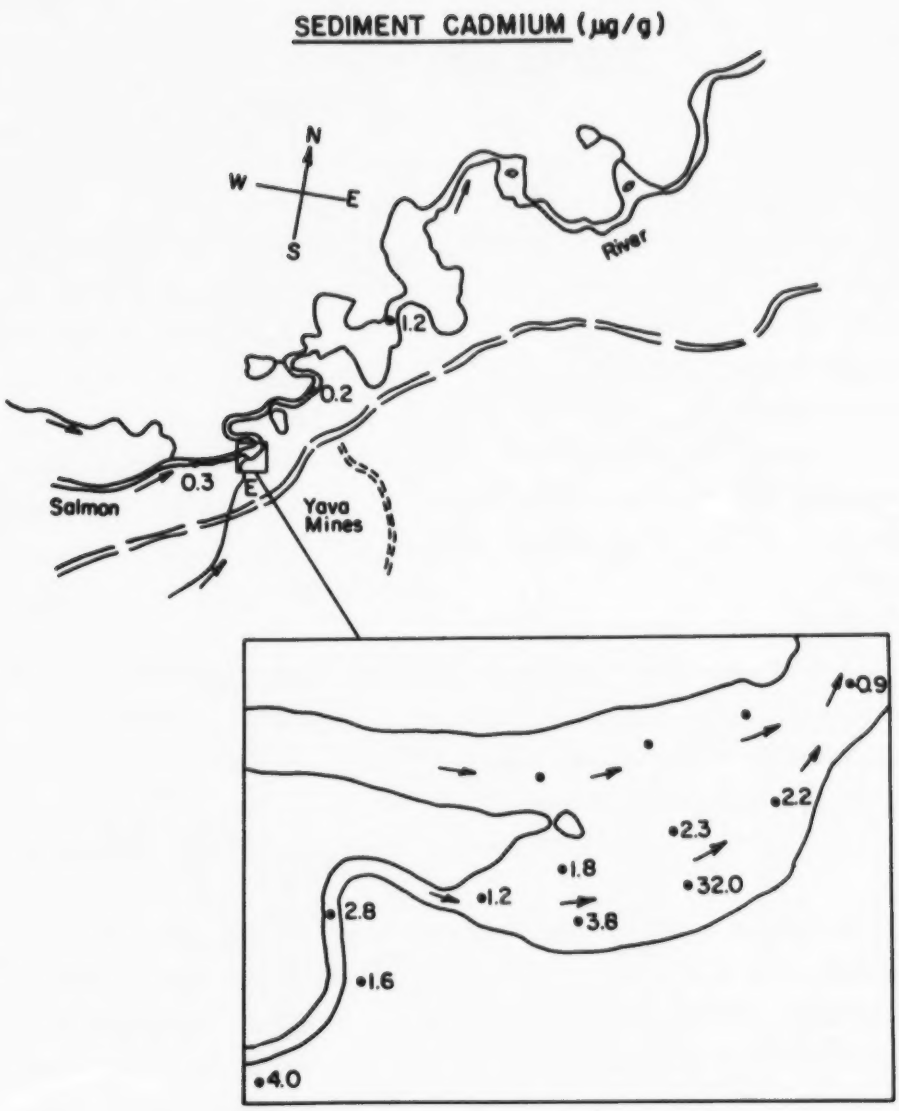


FIGURE 9 - SEDIMENT CADMIUM CONCENTRATIONS (DRY WEIGHT) IN THE SALMON RIVER IN THE VICINITY OF THE YAVA MINES DISCHARGE

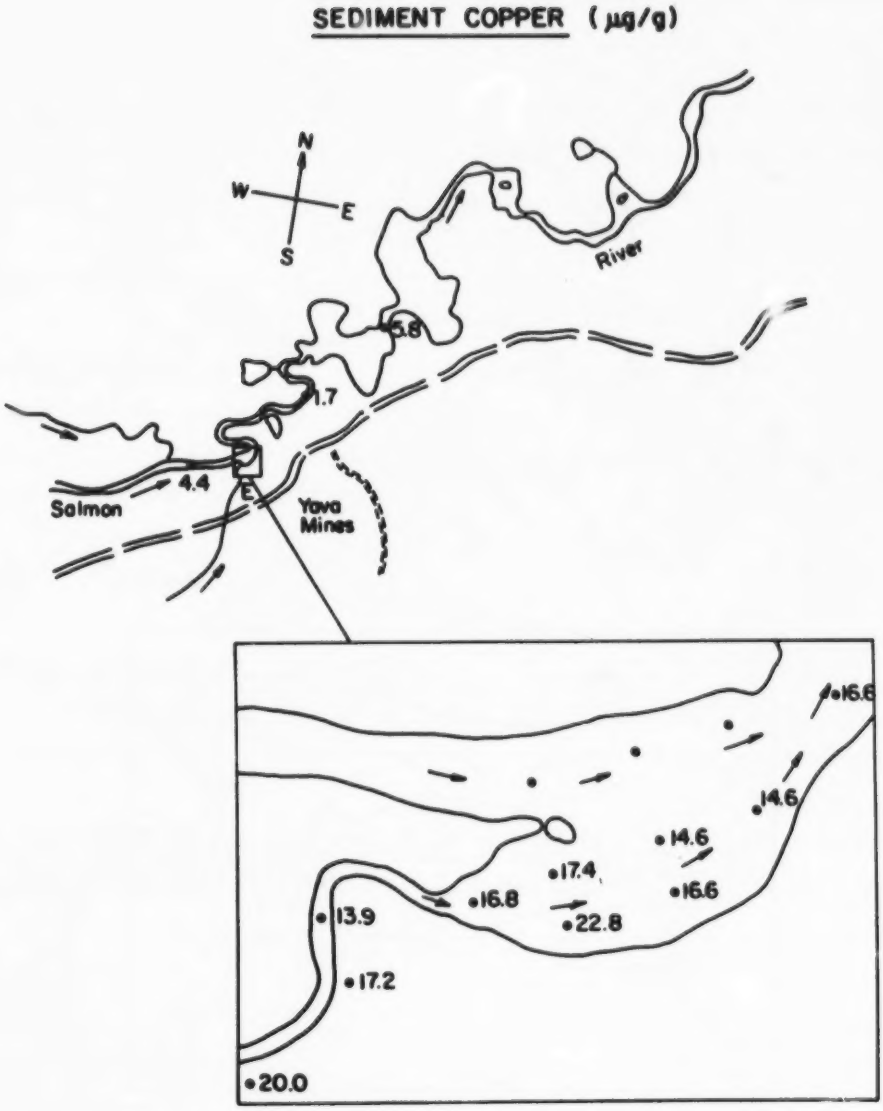


FIGURE 10 - SEDIMENT COPPER CONCENTRATIONS (DRY WEIGHT) IN THE SALMON RIVER IN THE VICINITY OF THE YAVA MINES DISCHARGE

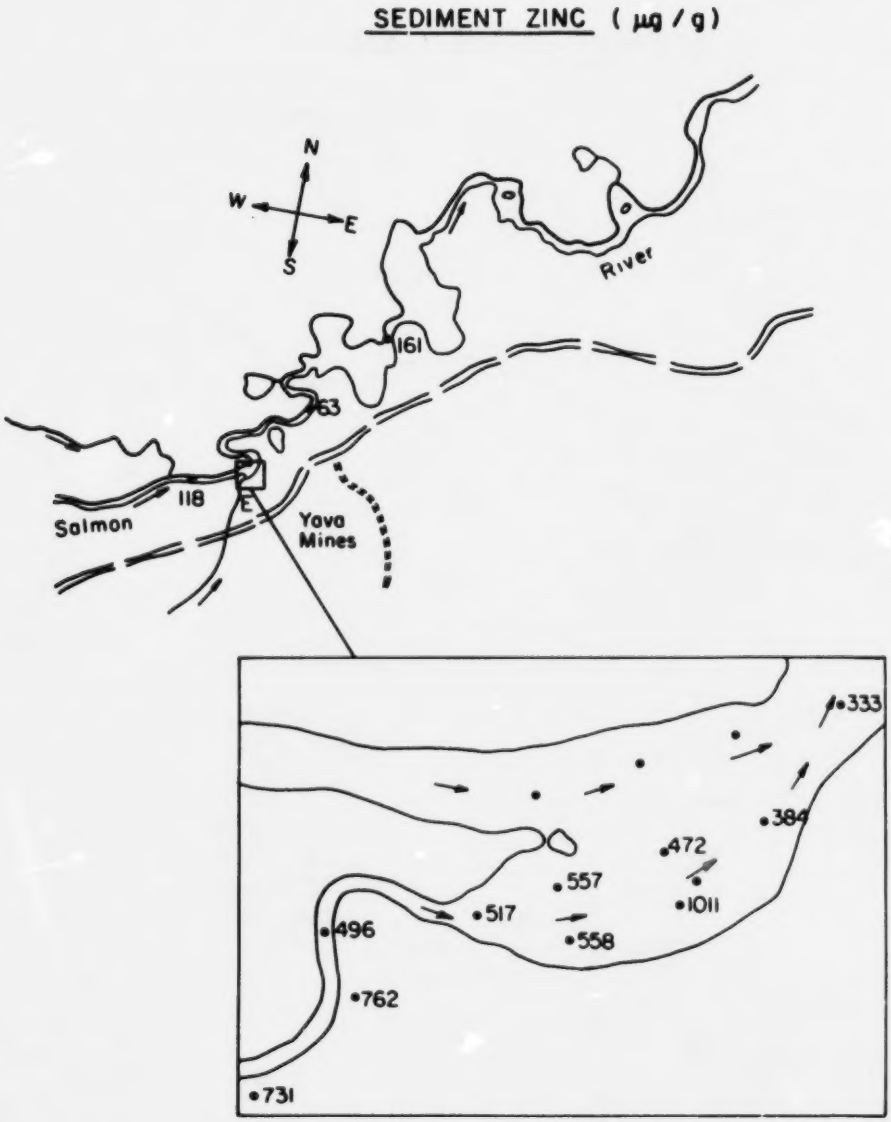


FIGURE 11 - SEDIMENT ZINC CONCENTRATIONS (DRY WEIGHT) IN THE SALMON RIVER IN THE VICINITY OF THE YAVA MINES DISCHARGE

TABLE 4 - BENTHIC INVERTEBRATES - SALMON RIVER SURVEY

Station 1 - midstream of river where it leaves the first large pond downstream of Yava Mines discharge (second downstream station, rock bottom at approximately 1.8 m^3/sec.).

Class - Insecta

Genus Cyrnellus	- No. 1
Genus Chrysops	- No. 1
Genus Odontonyia	- No. 1
Family (probably Polycentropodidae)	- No. 2 (unidentifiable)

Class - Pelycopoda

Genus Margaritifera	- No. 2

Station 2 - 20 metres upstream of bridge at the Yava Mines discharge (first downstream station, rock bottom at approximately 1.8 m^3/sec.).

Class - Insecta

Genus Helicopsyche	- No. 1
Genus Sialis	- No. 2
Genus Chrysops	- No. 1

TABLE 4 (Continued)

Station 3-1 - in cove directly at mouth of Yava effluent discharge (mud bottom - slow flows).

Class - Oligochaeta

Cligochaeta	- No. 85

Class - Insecta

Genus Tabanus	- No. 1
Genus Bezzia and/or Probezzia	- No. 2

Order Diptera

Family Dolichopodidae	
Genus Argyra (probably)	- No. 1

Station 3-2-C - rock and gravel, in main stream 20 m.

Class - Insecta

Order Coleoptera	
Family Elmidae	
Genus Optioservus	- No. 2

TABLE 4 (Continued)

Order Ephemercptera	
Family Tricorythidae	
Genus Tricorythodes	- No. 1
Family Leptophelibridae	
Genus Paraleptopherbia	- No. 1
Order Thicopter	
Unidentifiable	- No. 1
Genus Leuctra	- No. 2
Genus Pentaneura	- No. 9
Genus Stenelmis	- No. 2
Genus Psephinus	- No. 1
Genus Ophiogomphus	- No. 1
Genus Stenonema	- No. 1
Class - Oligochaeta	
Genus Oligochaeta	- No. 3
Class - Pelycopoda	
Genus Margaritifera	- No. 1

The diatom samples have been cleared and mounted, but resources for identifying the algae are not available at present. The part of this report dealing with the diatom results, therefore, will have to be deferred until time can be made available.

4. DISCUSSION

It is clear that the mining activity and land wash from highly mineralized areas on the Salmon River has resulted in a heavily contaminated sediment at the point of discharge.

The mining activity has contributed to this contamination, although the actual mechanism of contamination, that is, whether it is due to the continuous discharge from the settling ponds or from isolated incidents, remains obscure. The orders of magnitude of these contributions can be approached by rough loading calculations. During its life, the mine has discharged in the order of 1.5 million cubic metres at concentrations varying from 0.2 mg/l to 20 mg/l. The total lead discharged would therefore be in the order of 300 to 30,000 kg. For comparison, a three day spill of untreated mine water (59 mg/l at 15,000 m^3) would release at most 750 kg lead. Even with these crude calculations, one can see that spills of this kind can contribute significantly to the contamination of the river, yet the normal discharge, regardless of whether it satisfies the Base Metal Regulations requirements, also contributes significantly.

Before the mine began operations and modified drainage, by diversion ditches and recontouring, there were two small streams entering the Salmon River through the small cove where most of the detailed sampling of this study was done. As indicated by Geisler (1962), these streams passed through highly mineralized soils. Although Geisler did not report analyses from the cove itself, it is probable that some portion of the heavy metal levels in the cove came from this source. The relative contributions from this and from the mining activities is not clear.

While it is not the purpose of this report to discuss the environmental effects of heavy metal contamination in sediments, a brief summary would be useful to put this problem in context, but only a highly simplified account can be described here. For further information, the reader is directed to a number of reviews: Spear and Pierce, 1979; Spear, 1981; Jawarski, 1978; McV. Clarke, 1974; Anonymous, 1979.

The fact that there are large metal sulphide ore bodies attests to the fact that the main chemical mechanism for these metals is precipitation of insoluble sulphides and the occasional redistribution of these sulphides. The chemistry of the metals in water is extremely complex and interactive. Chemical speciation depends on pH, hardness, and other environmental variables. From the point of view of ecology of the receiving water, the important thing is that some of these metals, when released either by man's activities or nature's, tend to increase the concentrations of these materials in the tissues of organisms. In some cases, lethal concentrations are reached, particularly for larval forms. One generalization that has been made is that higher trophic levels tend to have higher concentrations of metals. Planktonic and attached algae usually have the highest body burdens, but care should be taken in evaluating such data since algal mats can act as filters for suspended particles and much of the contamination is adsorbed.

Molluscs are also among the best concentrators of metals, presumably because they are exposed to large volumes through their filter feeding. Other invertebrates and fish, on the other hand, tend to have relatively low concentrations, yet even these can reach levels that cause concern for human consumption. This is particularly true for cadmium and lead for which human body burdens from other sources are thought by some to be already at critical levels. The greatest threat to the environment, however, is the complex series of changes that have been observed to occur near many mining operations, resulting in no life or abundant life with little variety. Both of these are signs of a stressed environment.

At the present, damage to the ecology of the Salmon River appears to be localized, although concentrations of metals in the tissues of animals in the river is not yet available. There are a number of factors that may some time in the future mobilize or disperse this contamination. Erosion, through major storms and movement of ice, may be a primary mechanism for this while changes in pH, salinity, or oxygen, can effect the amount of metal released from the sediment. Low pH, which is of concern in Canada because of the general tendency of our lakes and rivers towards decrease, may release metals from the sediment. Fortunately, the Salmon River does not appear to be in one of the low pH areas. High salinity tends to pull heavy metals out of solution. This is why high sediment concentrations have been observed in the salt wedges of many estuaries. The Mira River, therefore, may have areas of high sediment concentration Oxygen is also an important factor, and it is thought that when sediments are oxygenated, metals tend to be released into solution.

It is important, therefore, not only that the discharge be controlled at least to below the 0.4 mg/l lead as stated in The Base Metal Mining Regulations, and that incidents such as the one occurring in March, 1981, be avoided, but also that the results of former spills and discharge on the sediment contamination be cleaned up in some manner. For the latter, there is more than one possibility. First, a coffer dam or curtain might be placed at the edge of the cove and the contaminated sediments "mucked" out for proper disposal. Secondly, the stream might be diverted around the contaminated segment and the contamination removed or stabilized in some way. Thirdly, the stream might be diverted temporarily to permit removal of the contamination, then returned to its original channel. Without detailed biological and engineering studies of these alternatives, it is not possible yet to decide which would be feasible and which would cause the least spread of the heavy metals.

The sediments of the Salmon river that have been contaminated with heavy metals may not necessarily stay at their present location, on the bottom. Various conditions could bring about their movement. A lowering of pH in the river for such reasons as long range transport, or further industrial development on the watershed, would tend to mobilize the heavy metals. Stream invertebrates or aquatic plants could accumulate these metals and eventually mobilize them. A study of this possibility could be carried out now since if it will occur it probably already has partially taken place. Flash floods might scour the bottom of the cove and the shoreline redepositing the bottom along the stream bed. Should such mobilization occur, it would be much more difficult to clean up.

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APPENDIX A

EFFLUENT QUALITY OF YAVA MINES MINE DRAINAGE AFTER TREATMENT

Date 1979	Average Flow m^3/hr	pH Field	Alkalinity (as $CaCo_3$) ppm	Mg ppm	Ca ppm	Hardness (as $CaCo_3$) ppm	Cu ppm	Zn ppm	Pb ppm	Al ppm	Cd ppm	Suspended Solids ppm	Sampled by	Analyze by
Jan. 2	-	-	-	-	-	-	<0.05	<0.05	0.17	-	-	-	YAVA	YAVA
Jan. 2	-	-	-	-	-	-	<0.05	<0.05	0.20	-	-	-	YAVA	YAVA
Nov. 20	-	7.3	55	9.85	107	-	0.006	0.049	0.25	<0.02	0.002	-	EPS	EPS
Nov. 21	21.7*	6.3	-	-	-	308	0.024	0.04	0.025	<0.02	0.002	-	EPS	EPS
Nov. 28	-	7.0	-	-	-	-	<0.001	0.113	0.176	-	<0.001	5.3	YAVA	AIRI
Dec. 5	-	7.6	-	-	-	-	0.010	0.080	0.326	-	<0.001	<1	YAVA	AIRI
Dec. 13	-	-	-	-	-	-	<0.05	<0.05	0.33	-	-	-	YAVA	YAVA
Dec. 21	-	-	-	-	-	-	<0.05	<0.05	0.33	-	-	-	YAVA	YAVA

* Point measure, not average.

APPENDIX A

EFFLUENT QUALITY OF YAVA MINES MINE DRAINAGE AFTER TREATMENT (Continued)

Date 1980	Average Flow m^3/hr	pH Field	Alkalinity (as $CaCo_3$) ppm	Mg ppm	Ca ppm	Hardness (as $CaCo_3$) ppm	Cu ppm	Zn ppm	Pb ppm	Al ppm	Cd ppm	Suspended Solids ppm	Sampled by	Analyzed by
Jan. 9	-	-	-	-	-	-	<0.01	<0.05	0.45	-	-	-	YAVA	YAVA
Jan. 9	-	-	-	-	-	-	<0.01	<0.05	0.47	-	-	-	YAVA	YAVA
Jan. 16	-	-	-	-	-	-	<0.016	0.08	0.39	-	-	-	YAVA	YAVA
Jan. 16	39.1	7.4	-	-	-	-	0.001	0.080	0.230	-	<0.001	<1	YAVA	AIRI
Jan. 31	-	-	-	-	-	-	<0.002	0.07	0.48	-	-	-	YAVA	YAVA
Feb. 6	35.6	7.9	-	-	-	-	<0.001	0.065	0.360	-	<0.001	<1	YAVA	AIRI
Feb. 6	-	-	-	-	-	-	<0.002	0.07	0.38	-	-	-	YAVA	YAVA
Feb. 16	-	-	-	-	-	-	<0.001	0.08	0.37	-	-	-	YAVA	YAVA
Feb. 27	-	-	-	-	-	-	<0.001	0.06	0.43	-	-	-	YAVA	YAVA
Mar. 11	40.2	7.5	-	-	-	-	<0.001	0.070	0.380	-	<0.001	11.2	YAVA	AIRI
Apr. 9	45.6	7.4	-	-	-	-	<0.001	0.040	0.280	-	<0.001	7.5	YAVA	AIRI
May 9	50.8	7.3	-	-	-	-	0.002	0.061	0.600	-	<0.001	-	YAVA	AIRI
June 10	53.6	7.35	-	-	-	-	0.008	0.070	0.700	-	<0.001	18.1	YAVA	AIRI

APPENDIX A

EFFLUENT QUALITY OF YAVA MINES MINE DRAINAGE AFTER TREATMENT (Continued)

Date 1980	Average Flow m^3/hr	pH Field	Alkalinity (as $CaCO_3$) ppm	Mg ppm	Ca ppm	Hardness (as $CaCO_3$) ppm	Cu ppm	Zn ppm	Pb ppm	Al ppm	Cd ppm	Suspended Solids ppm	Sampled by	Analyzed by
July 8	51.3	7.5	-	-	-	-	0.002	0.063	0.400	-	0.01	<0.001	YAVA	AIRI
Aug. 4	-	7.1	-	-	-	-	0.005	0.019	-	-	<0.01	1.8	YAVA	AIRI
Oct. 30	-	-	-	9.20	88.0	260	0.016	0.06	0.72	0.64	<0.01	-	EPS	EPS
Nov. 21	-	7.4	-	-	-	-	0.005	0.128	0.940	-	<0.001	43.7	YAVA	AIRI

APPENDIX A

EFFLUENT QUALITY OF YAVA MINES MINE DRAINAGE AFTER TREATMENT (Continued)

Date 1981	Average Flow m^3/hr	pH Field	Alkalinity (as $CaCo_3$) ppm	Mg ppm	Ca ppm	Hardness (as $CaCo_3$) ppm	Cu ppm	Zn ppm	Pb ppm	Al ppm	Cd ppm	Suspended Solids ppm	Sampled by	Analyzed by
Jan. 9	85.1*	7.8	-	-	-	-	0.004	0.070	0.64	-	<0.001	11.6	YAVA	AIRI
Feb. 6	57.1	7.2	-	-	-	-	<0.001	0.063	0.56	-	<0.001	12.8	YAVA	AIRI
Mar. 4	68.1	7.1	-	-	-	-	0.012	0.141	0.26	-	<0.001	<1	YAVA	AIRI
Mar. 12	-	-	-	-	-	-	<0.01	0.04	1.3	3.0	<0.005	-	YAVA	AIRI
Mar. 19	-	7.9	64	7.6	85	245	0.01	0.07	0.10	0.49	<0.005	8.0	NSDOE	PATH
Mar. 31	-	-	-	-	-	-	<0.01	0.03	0.51	1.9	<0.005	22	NSDOE	PATH
Apr. 1	85.1*	7.8	-	-	-	-	<0.01	<0.01	0.50	-	<0.01	90	EPS	EPS
Apr. 7	-	-	-	-	-	-	0.01	0.07	1.58	7.6	<0.005	103	NSDOE	PATH
Apr. 13	68.1	7.7	-	-	-	-	0.014	0.160	21.400	-	0.001	7.8	YAVA	AIRI
Apr. 24	-	-	-	-	-	-	<0.01	0.06	2.0	9.6	<0.005	128	NSDOE	PATH
May 8	-	-	-	-	-	-	<0.01	0.02	0.38	2.2	<0.005	18	NSDOE	PATH
June 4	117.1*	-	-	-	-	-	-	-	2.28	-	-	-	YAVA	YAVA
June 9	94.5	6.0	-	-	-	-	0.002	0.077	0.490	-	<0.001	19.8	YAVA	AIRI

APPENDIX A

EFFLUENT QUALITY OF YAVA MINES MINE DRAINAGE AFTER TREATMENT (Continued)

Date 1981	Average Flow m^3/hr	pH Field	Alkalinity (as $CaCo_3$) ppm	Mg ppm	Ca ppm	Hardness (as $CaCo_3$) ppm	Cu ppm	Zn ppm	Pb ppm	Al ppm	Cd ppm	Suspended Solids ppm	Sampled by	Analyzed by
June 12	82.0*	-	-	-	-	-	-	-	0.50	-	-	-	YAVA	YAVA
June 12	-	-	-	-	-	-	<0.01	0.03	0.55	0.03	<0.005	-	NSDOE	PATH
June 19	82.0*	-	-	-	-	-	-	-	0.38	-	-	-	YAVA	YAVA
June 26	-	-	-	-	-	-	<0.01	0.02	0.38	2.2	<0.002	15	NSDOE	PATH
June 29	100.2*	-	-	-	-	-	-	-	0.31	-	-	-	YAVA	YAVA
July 10	-	-	-	-	-	-	0.03	0.11	0.389	1.3	<0.002	17	NSDOE	PATH
July 24	-	7.8	81	9.6	122	350	<0.01	0.02	0.39	1.7	-	18	NSDOE	PATH
Aug. 7	-	-	-	-	-	-	<0.01	0.03	0.283	1.3	<0.001	-	NSDOE	PATH
Aug. 7	-	7.9	65	10	113	324	<0.01	0.04	0.303	-	-	21.8	NSDOE	PATH
Aug. 21	-	-	-	1.0	-	-	<0.01	0.10	3.3	11	<0.002	234	NSDOE	PATH
Sept. 2	-	-	-	-	-	-	*	-	-	-	-	14	NSDOE	PATH

* Point measure, not average.